# Microwave Signal Mixing by Using a Fiber-Based Optoelectronic Oscillator for Wavelength Division Multiplexed (WDM) Systems

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Two WDM channels at 1320 nm and 1312 nm carrying RF signals arc simultaneously up/down converted by a fiber-based optoelectronic oscillator. The conversion efficiency are found to be ~ -8 dB and the incoming signals has no effects on the local oscillator spectrum purity.

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Fiber optics has been rapidly penetrating into the microwave systems as the advancement of the optical component technology. in additional to microwave transmission for subcarrier systems [ 1 ] and satellite communications [2], many new capabilities has been demonstrated such as microwave generat ion, filtering and mixing, which arc traditional] y performed by the microwave electronics. Additionally, emerging wavelength division multiplexing technology not only finds its place in increasing the system capacity, but also in microwave signal processing such as true time delay control for phased array antenna systems[3]. A novel microwave fiber-optic link has been proposed where the information data is up/down converted by two external modulators [4]. Such a scheme offers advantage of avoiding need of high speed photodetectors and microwave mi xers. However , onc difficult task still remain that the electrical local oscillator (1.0) is needed. The high frequency LO is generally obtained by multiplying a low frequency standard (i.e. 10 MHz,) through numerous stages of multiplier and amplifiers, which is bulky and cumbersome. Recently, a new kind of fiber-basccl photonic oscillator has been proposed and demonstrated [5]. Such a oscillator can generate microwave with high spectrum purity up to '7S GHz and many interesting capabilities such as subcarrier/clock recovery and microwave regeneration have been demonstrated. Wc propose a ncw functionality for this microwave oscillator, i .c., photonic microwave mixing for WDM systems [Fig. 1a]. In this approach, WDM channels carrying RF signals arc simultaneously down converted to 1 F by a fiber-based local oscillator, and detected by low speed detector arrays. in the demonstration, RF signals carried on the wavelengths of 1320 nm and 1312 nm are simultaneously down/up converted by the photonic oscillator at - 5 GHz. The conversion efficiency is found to be -8 dB and the local oscillator spectral purity is not affected by the incoming signals.

The photonic oscillator is basically a microwave cavity with the open loop gain larger than 1 [fig. lb]. The cavity consists of the optical pumping light being modulated by a external modulator, transmitted by a fiber delay line, detected by a photodetector, electrically amplified and feed back into the modulator RF drive port. lust as a fiber based ring laser, utilizing a fiber delay offers the advantage of effective high-Q cavity which results superior RF spectrum purity. Using the local oscillator as a mixer eliminates the problems of RF isolation and RF power sharing bet wccn the modulator and the local oscillator. Although a high speed detector and a modulator arc used in the local oscillator, the cost is highly justified by the resulting spectra] purity of RF generated by this approach, especially for the high frequency in millimeter wave range. Fig.1b also shows the experimental setup. Two optical signals at 1320 nm and 1312 nm arc modulated at around 6 GI 1 z with frequencies 50 Ml Iz apart. The combined signal arc used to simulate the WI )M signals which will be processed by the optoelectronic oscillator. The pump for the oscillator is at 1543 nm. The power into the modulator is -6.5 dBm, -4.5 dBm, and 6 dBm for 1320 nm, 1312 nm and 1543 nm respectively. Onc output is coupled into the oscillator loop and passes through a 1.5 um filter which attenuates 1.3 um signals with a 60 dB rejection ratio. The signals from the other port are detected and monitored by a HP RF spectrum analyzer. The fiber delay of the oscillator is about 1 km and the mode selection is done by electrically injecting -50 dBm RF signals at 5.17 GHz. The resulting signal to side-nmdc ratio is over 65 dB. The advantage of this type of oscillator is that it could be either remotely injection-lockcci and synchronized by injecting optical signal or locally synchronized by injecting electrical signals.

Figures 2a, 2b and 2c show the measured R]; spectra at the output of the local oscillator. Fig. 2a shows the two unconverted RF signals around -6 GHz. Fig. 2b shows the down converted signals around -800 MHz. Figure RF shows up converted signals around 11 GHz. The input power into the optical detector arc -13.8 dBm and -11.50 dBm for 1320 mn and 1312 nm respectively. The RF power from detector is amplified by about 20 dB.

Figure 3 shows the performance of the oscillator. Fig. 3a shows the detected converted power as a function of the detected unconverted signals at 6 GHz. The conversion is very linear and nearly 1 dB increase of the unconverted signal power results 1 dB increase of converted signs]. ']'here is around 4 dB difference bet wccn up-converted and down-converted signals. This is mainl y duc to the response of the optical detector and RF cable. Further more, the curve for these two wavelengths (1320 nm and 1312 nm) arc identical, implying the perfect operation for the WDM systems. Most significant] y, the conversion efficiency ( the ratio between the converted signals and unconverted signal ) is around -8 dB, oniy 2 dB penalty in comparison to a perfect conversion which is -6 dB. Note wc on] y use -50 dBm injection RF power, the open loop RF power at the modulator for this injection signal is 12 dBm. However, the oscillation RF power at modulator is 25 dBm, implying a 13 dB RF gain for this oscillator. Also the phase noise duc **to** the electrical amplifier is greatly reduced by this high-Q fiber microwave cavity. Finally, the oscillator itself is not affected by processing the signals because they arc effectively rejected by the optical filter. Fig. 3b shows the spectrum of the oscillator and wc found no visible difference whether the WDM signals arc injected or not,

## Figure Captions

1. (a) Conceptual diagram of the new functionality of the fiber optoelectronic oscillator, (b) Experimental setup

2. Measured RF spectrum for (a) input RF signal @ 6 GHz, (b) down-converted signal @ 1 GHz, and (c) up-converted signal @ 11 GHz. Both RBW and VBW are 10 kHz.

3. Performance of the oscillator: (a) the output converted RF power as a function of the unconverted RF power, and (b) the spectrum of the local oscillator for the cases (1) the signals are not injected, (2) the signals are injected.

## References


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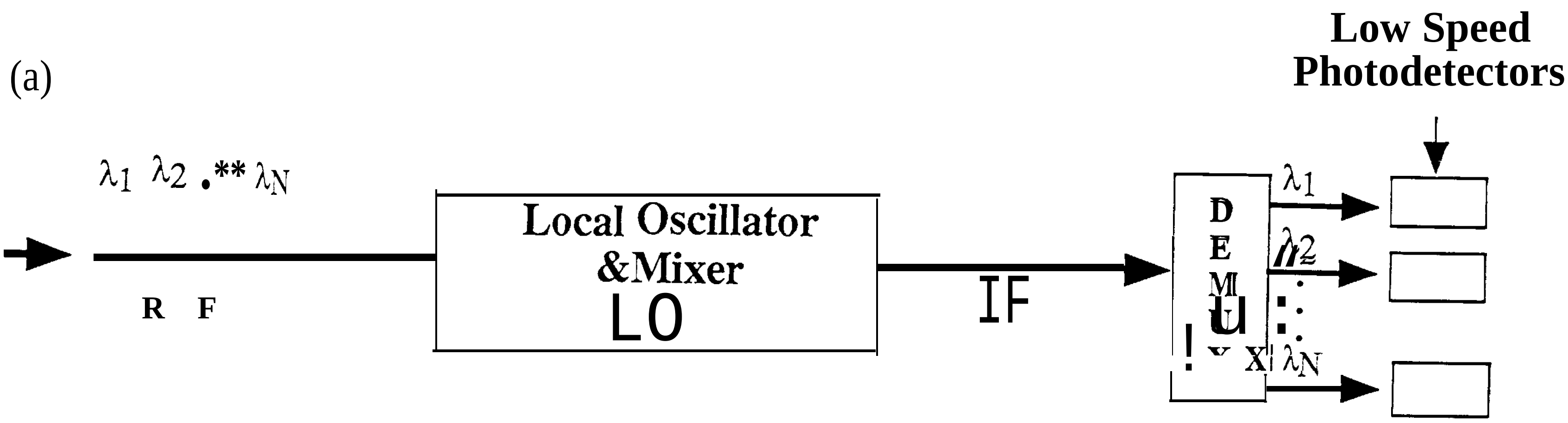
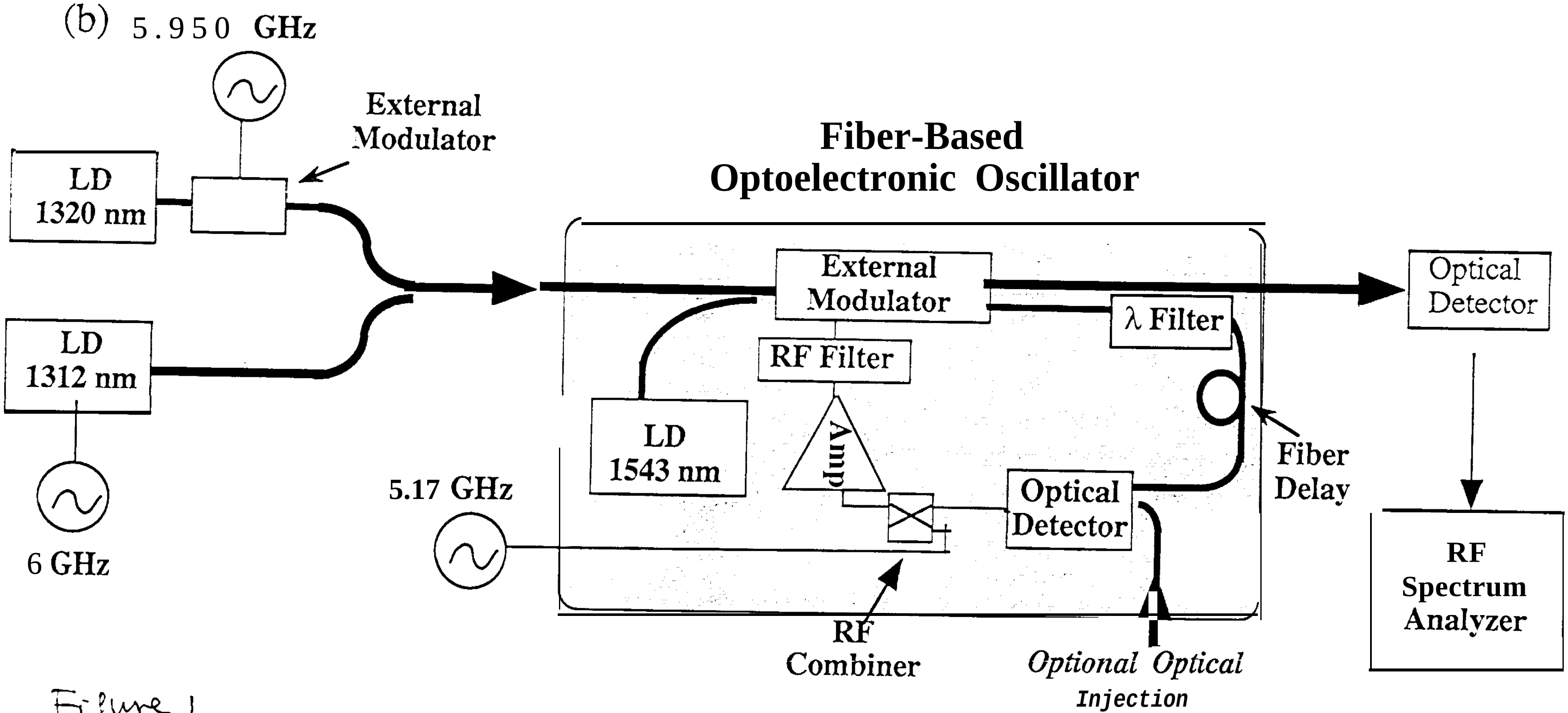
(a)



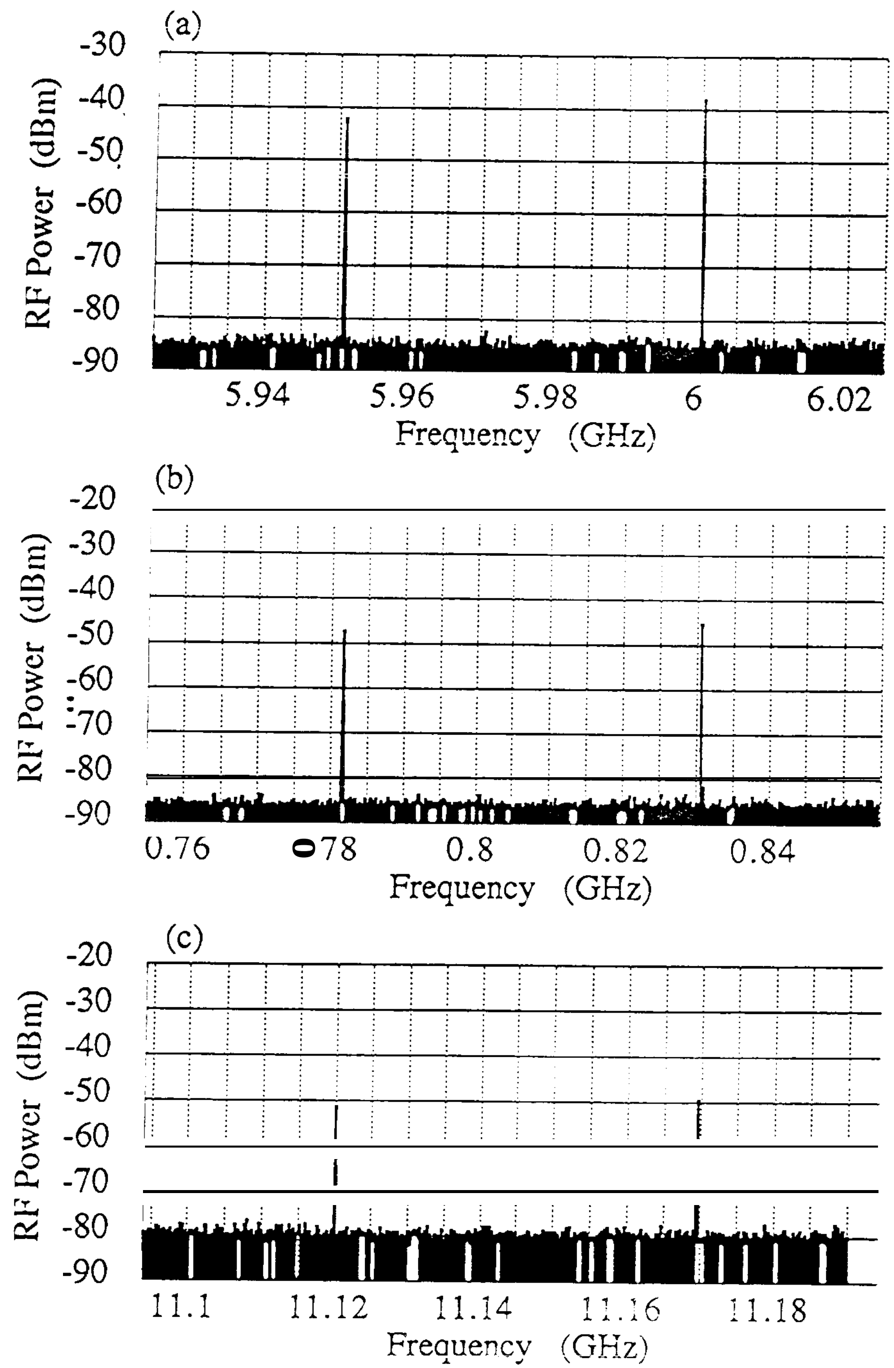
Low Speed
Photodetectors
λ1 λ2 .** λN
R F
Local Oscillator
&Mixer
LO
IF
D
E
M
U
X
λ1
λ2
λN


(b)



5.950 GHz
External
Modulator
LD
1320 nm
LD
1312 nm
6 GHz
Fiber-Based
Optoelectronic Oscillator
External
Modulator
λ Filter
Optical
Detector
RF Filter
LD
1543 nm
Amp
5.17 GHz
Optical
Detector
Fiber
Delay
RF
Combiner
Optional Optical
Injection
RF
Spectrum
Analyzer


Figure 1



(a)
-30
-40
-50
-60
-70
-80
-90
RF Power (dBm)
5.94
5.96
5.98
6
6.02
Frequency (GHz)
(b)
-20
-30
-40
-50
-60
-70
-80
-90
RF Power (dBm)
0.76
0.78
0.8
0.82
0.84
Frequency (GHz)
(c)
-20
-30
-40
-50
-60
-70
-80
-90
RF Power (dBm)
11.1
11.12
11.14
11.16
11.18
Frequency (GHz)


Figure

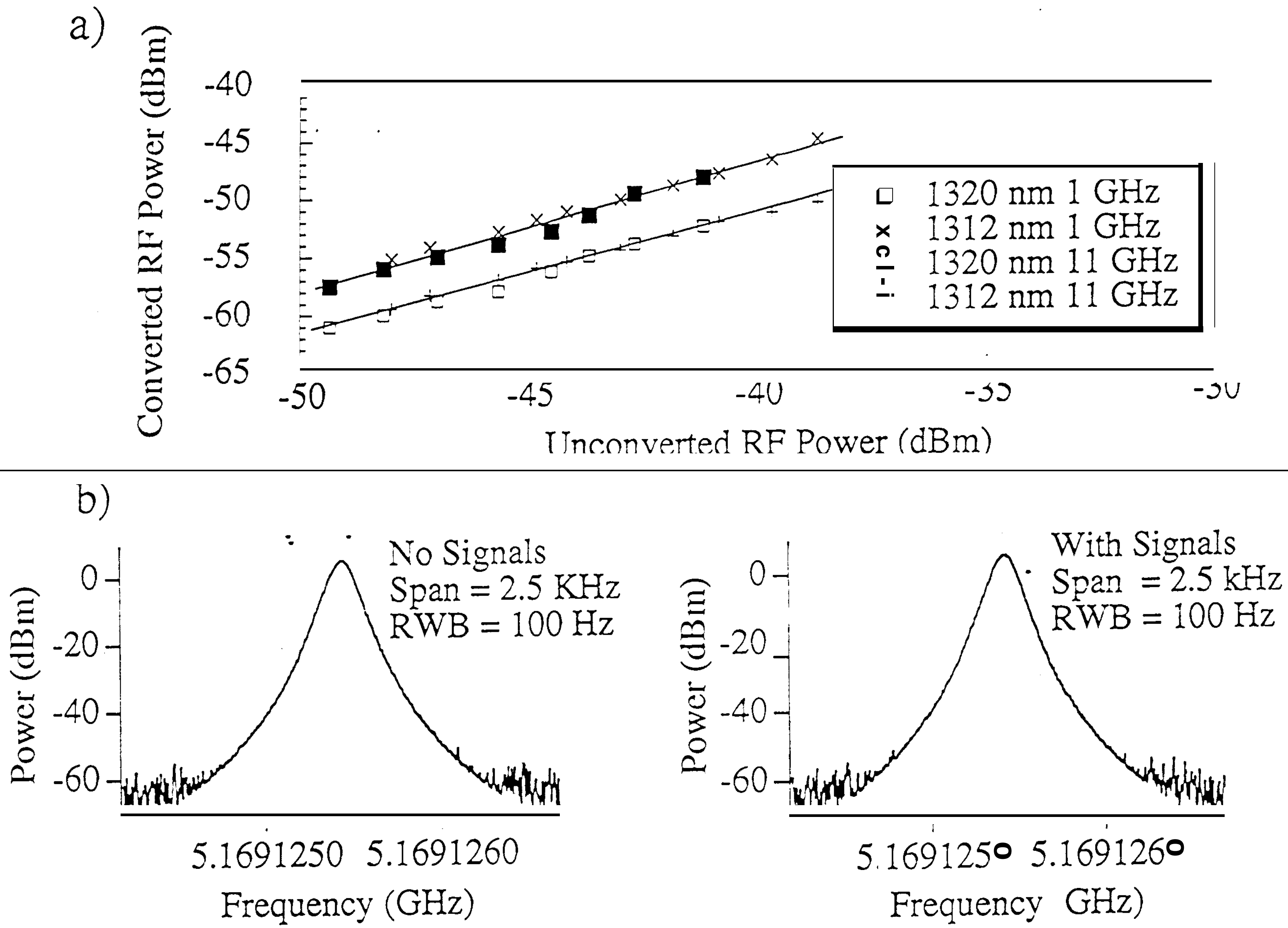

a)
Converted RF Power (dBm)
-40
-45
-50
-55
-60
-65
-50
-45
-40
-35
-30
Unconverted RF Power (dBm)
1320 nm 1 GHz
1312 nm 1 GHz
1320 nm 11 GHz
1312 nm 11 GHz
b)
Power (dBm)
0
-20
-40
-60
No Signals
Span = 2.5 KHz
RWB = 100 Hz
5.1691250 5.1691260
Frequency (GHz)
Power (dBm)
0
-20
-40
-60
With Signals
Span = 2.5 kHz
RWB = 100 Hz
5.1691250 5.1691260
Frequency GHz)

Figure 3